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NUSAT Update

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This paper presents, in general terms, the results of the experiments with NUSAT I. These include what has been learned about the strengths of the original design, as well as improvements being incorporated into NUSAT II, which should be of interest to designers of future Get Away Special ejected satellites. This paper also presents an account of the formation of the Center for AeroSpace Technology (CAST) at Weber State College, which grew out of the NUSAT project, and some potential applications and markets for inexpensive, low orbit satellites which CAST has explored.

THE GOALS OF THE NUSAT I PROJECT

NUSAT I was a small, 105 pound satellite ejected from the orbiter, Challenger, shortly after the launch of mission 51B on April 29, 1985. The principal experiment on board NUSAT I was an L-band measurement system to determine the vertical radiation pattern of air traffic control radar antennas. This information would then be used to optimize the coverage volume of these radars.

The NUSAT project was organized with three stated goals:

- to provide an exciting, real life educational experience for students;

- to test the Get Away Special (GAS) canister as a platform for ejecting small satellites into independent orbit; and

- to demonstrate a technique for measuring the vertical radiation patterns of large vertical aperture antennas.

Some implied goals were:

- to test the effectiveness of an ad hoc, volunteer organization comprised of individuals from academia, industry and government;

- to enhance awareness of Northern Utah as a center of aerospace activity; and

- to facilitate networking of aerospace technologists.

NUSAT I EXPERIMENT RESULTS

Contact was established with NUSAT I a few days after launch and continued until July 15, 1985. However, communications during this period were characterized by low reliability. After a period of optimizing the ground station facilities and improving operator proficiency, it became clear that there was at least one problem on board the satellite. Many possibilities were considered including antenna orientation, solar cell or battery failure, interference, abnormal temperatures, and others, most of which could only be determined by the acquisition of sensor data. Eventually this data was obtained and indicated that the system temperatures and voltages were normal. Since only very short programs could be uploaded successfully, several other experiments could not be completed before all contact was lost in July.

Following a thorough recheck of the ground station it was assumed that the satellite had failed. Nevertheless, routine attempts to communicate with the satellite continued with no success. Ironically, during the early evening of November 23, 1985, while several participants were gathering to prepare a final, pessimistic report to the Federal Aviation Administration project coordinator, a half-hearted attempt to contact the satellite was successful! A number of new experiments were formulated based upon the observed system behavior and recently enhanced capabilities of the ground station, such as doppler compensation under software control. For example, it was noticed that the ground station room was unusually cold the night of reacquisition and the possibility of frequency drift on the satellite was considered. Eventually, it was determined that the modem clock on board NUSAT I had shifted and was compensated for by adjusting the ground station system.

Since last November, communications with NUSAT I have been very reliable, allowing routine uploads of long programs and successful downloads of large masses of data. One common operation has been the downloading of sensor data collected at various increments during an entire orbit. This has allowed study of the behavior of the power system while illuminated and shaded, as well as, analysis of platform attitude using the light sensor data. Another frequent operation has been the collecting of L-Band signal data while using unique interrogation modes from Federal Aviation Administration and Air National Guard radars in Utah. In addition, several experiments have been conducted with: Montana State University, an astronomer in Texas, amateur radio operators, even successful communications with a handheld transceiver!

The results of over a year of operation and experimentation with NUSAT I support the following conclusions:

1. The GAS canister is an excellent, low cost, vehicle for injecting a small satellite into low altitude, circular orbits. NUSAT I was ejected at an altitude of 360 km which had decayed to 305 km by June 1986. The orbit eccentricity was very low with a difference between apogee and perigee of about 8 km at that time.

2. It is possible to achieve reliable open-loop tracking of low orbit satellites using very inexpensive equipment operated by relatively inexperienced students. But an onboard beacon would simplify acquisition and tracking.

3. The enhanced flexibility permitted by the totally programmable philosophy implemented in NUSAT I is invaluable. Only the communications protocol, timing functions, security and fail-safe routines are in firmware on the satellite. All operational programs are uploaded from the ground station, which has allowed operational changes and experiments unthought of prior to launch.

4. Physical accessibility to internal components is an important consideration in the mechanical design of a small, but complex, satellite. Several post-assembly repairs and changes to NUSAT I were very difficult to accomplish.

5. Attitude determination by light sensors alone is a very complex, inaccurate process, especially when the spectral and directional characteristics of the sensors are not thoroughly measured prior to launch....

6. The time domain pulse discrimination technique used in the Federal Aviation Administration experiment on NUSAT I may be inadequate for use in the dense L-Band pulse environment over the United States and Europe.

NUSAT II DESIGN IMPROVEMENTS

A number of changes are being incorporated into the design, construction and operation of NUSAT II and subsequent satellites being planned by the Center for Aero-Space Technology. Some of these changes are influenced by NUSAT I experience, others are due to the availability of resources and devices not available at the time of NUSAT I's design and construction. These improvements include:

1. A full-time, low duty cycle Morse code telemetry beacon. The transmissions will contain spacecraft environmental and system parameter data which can be received by interested parties around the globe without unique equipment or knowledge. This beacon, combined with a high gain synthetic aperture antenna system on the ground, will enhance acquisition and tracking with less precise orbit predictions than those required for NUSAT I operations.

2. System redundancy. The availability of more powerful computers and larger memories requiring less current permit designs including completely redundant computers, expanded memory and dual communications systems. In addition, two isolated battery packs will be installed.

3. A cylindrical form. This will enclose a greater volume, simplify accessibility during integration and testing, increase solar panel/antenna area and enhance attitude control with more flexibility for changing moments.

4. An improved software communications protocol. A system employing error correcting codes, packet transmissions, etc., will be used to improve communications reliability under low signal-to-noise conditions.

5. An enhanced attitude measurement/control system which will increase the usefulness of presently planned experiments and provide experience and data for future satellite systems. This system will include optical and television sensors, magnetometers and magnetic torque rods.

6. Support for other experiments. NUSAT II will have sufficient volume, power and control to support additional experiments.

7. The Federal Aviation Administration L-Band system will include the following improvements:

- Two superheterodyne receivers instead of the present six TRF receivers. This will reduce power drain and increase system stability and flexibility.

- A frequency domain pulse discrimination technique using FFT's. This will improve operation in dense RF pulse environments.

- Greater flexibility in antenna directional control achieved with a phased array antenna and/or selective use of attitude controlled gain antennas.

8. And, finally, a system and philosophy of project management that includes closer tracking and reporting of sub-system progress, uniform documentation standards, more frequent design reviews and closer coordination with the senior projects program.

FORMATION OF THE CENTER FOR AEROSPACE TECHNOLOGY

Following the successful design, construction, launch and operation of NUSAT I, it became apparent that many individuals wanted to continue their participation in similar enterprises. In addition, Weber State College experienced increased public interest and support, greater success recruiting high quality matriculants interested in aerospace technology and more success placing graduates in the aerospace industry. Therefore, several individuals who had been members of the NUSAT Executive Committee, and a few new participants, formed the Center for Aero-Space Technology at Weber State College.

The following is the Statement of Purpose and Goals of the Center for Aero-Space Technology:

"The Center for Aero-Space Technology is a non-profit organization of individuals from industry, education and government in association with Weber State College. The purpose of the Center is to propose, solicit, design and manufacture useful aero-space experiments, devices or systems, or to support similar enterprises in other Utah schools and organizations.

"The goals of the Center are:

- **to generate significant, practical and realistic technical experiences for students;**
- **to provide a local center for aero-space technologists to connect with others of similar interests, share their expertise with students and associates, and achieve other personal goals;**
- **to create an environment in Northern Utah which will support aero-space industries;**
- **and, to facilitate public aerospace education in Utah.**

"It is envisioned that future projects will be modeled after the NUSAT I project, in which its goals were achieved through a combination of student and volunteer efforts, donated resources and contracts with other organizations."

The Center for Aero-Space Technology is governed by a Board of Directors from the college, industry and government. A larger group of aerospace professionals serve as student group advisors. And the production teams are formed of senior project, and other, student groups working with faculty members and advisors to do the actual design, manufacturing and testing of systems.

Presently the Center employs a full-time director, a part-time consultant from the faculty and several part-time student operators and researchers. Funding for the Center comes from several sources including: a grant from the Utah State Board of Economic Development; a third contract with the Federal Aviation Administration; and a matching grant from Weber State College. Contracts with the Center are administered by the Director of Sponsored Projects at Weber State College.

The Center for Aero-Space Technology, as part of the Western Space Consortium, including Weber State College, Montana State University, University of Idaho and several corporations, has applied for a NASA grant under the Centers for Commercial Development of Space program. The Center has been invited to participate in two other consortiums one of which has received, the other has applied for, a similar NASA grant. The author is chairman of a sub-committee of the Satellite Operators and Users Technical Committee which is investigating a potential application for small low orbit satellites. Other members of the Board of Directors are pursuing similar projects within their own corporations, government agencies, SDIO, etc. The Center is continuously receiving communications from sources as varied as universities in Pakistan, government agencies in the United Kingdom, corporations in Japan, as well as, individuals, corporations, educators and government agencies in the United States. Some proposals have been beyond our capabilities and we have referred them to other organizations and others have been of questionable value, but several are being pursued as future projects for the Center.

LOW ORBIT SATELLITE APPLICATIONS

There are many potential applications requiring small, low orbit satellites. Some are in the area of communications and control, such as collecting environmental sensor and position/movement data from remote locations, remote management of power and irrigation system resources and many customized message delivery systems. A large variety of space-based sensor platforms are needed and a vast number of military projects require these satellites. A great deal of research is needed to specify and invent: the optimum communications systems; inexpensive and simple attitude determination and control systems; multi-spectrum sensors; materials testing systems for the low orbit environment; artificial intelligence for auto-operation of spacecraft systems; and many more....

For example, the Center is working with the Federal Communications Commission, the Satellite Operators and Users Technical Committee, and several colleges and corporations to develop and deploy a low orbit system to locate sources of interference with geo-stationary communications satellites. A similar system can be used to improve tracking and locating systems presently employing a meteorology satellite.

The Center is also pursuing several projects that are of interest to the Strategic Defense Initiative Organization.

The opportunities to improve existing systems and develop new systems are endless. There is so much work to be done that no individual organization needs to fear that others will steal all the opportunities.